Proposal for a PhD thesis

Hosting laboratory:

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Subject: Towards biobased concretes with tailored mechanical properties

Context

Biobased materials are increasingly integrated into the construction materials formulation to reduce the environmental impact of the building sector. For example, concretes made of plant aggregates embedded in a mineral binder are used for wall, floor and roof insulation. In France, construction rules have been established to regulate the use of hemp concrete. However, studies show that it is still impossible to predict the performance of these materials, especially mechanical, from the initial formulation of the concrete. This result is attributed to the physicochemical interactions between plant components and mineral binders, which can lead to modifications in the hydration mechanisms of the latter (Diquélou et al., 2016; Delannoy et al., 2020). Indeed, some molecules extracted from the plant (especially some sugars and polyphenols) have a retarding or even inhibiting effect on setting.

This PhD is part of the ANR BIO-UP project, whose objective is to make significant progress in the understanding of the functional properties of biobased concretes according to the type of plant and mineral binder used, taking into account their environmental impact.

Objectives

The objective is, first, to study the effect of the interfacial transition zone (ITZ) and the properties of aggregates (morphology and mechanical characteristics) on the overall behavior of green concrete at the composite scale. This task will perform several sets of mechanical tests in compression and shear. Digital Image Correlation technique (DIC) will be used to determine the stress paths and the stress transfer at the ITZ. The transfer of these stresses to the plant aggregate will be evaluated and will allow us to define the optimum mechanical strength for the investigated composites. Therefore, the global mechanical properties will be issued.

A 3D digital concrete model will be then developed by homogenization to quantify the effect of the ITZ on the mechanical properties of green concrete. This work will be performed in different steps: the model material with a single particle (so-called micro scale), then the material with different particles but without interactions between the interphases (meso scale) and then the composite with possible interaction between the interphases (macro scale). At the micro scale, we will use the results which allowed identifying the characteristics of the interphase. The mechanical properties of vegetal aggregates and binders are separately known or identified. These properties are then integrated into the meso model to deduce a global behavior. The same work will be done for the macro model experimented in the first stage of the project. The correlation obtained between the numerical model and the experiment should allow us to conclude on the feasibility of predicting the mechanical behavior knowing the formulations of the materials.

Methodology

In a first step, the methodology to observe ITZ around vegetal particles will be developed starting from Diquelou's work. The novelty consists on the monitoring of the formation by imaging with a high-definition camera to measure the kinetics of the formation of the ITZ surface. Depending on the test, crushed raw bioresource will be used to have a more homogeneous material in the form of a pellet, and different sizes of aggregates, representative of the vegetal particle size distribution of the material, will also be studied individually, then simultaneously to observe the interactions between their ITZ. The same work will be carried out with an inert material to obtain the reference of the matrix having no ITZ.

The overall behavior of green concrete will be assessed for progressive configurations: at the scale of one isolated pellet, on two interacting ITZ pellets, and on several interacting ITZ pellets to study the phenomenon of percolated ITZ. The results on the pellets from this task will be transposed and scaled up on isolated vegetal particles.

The second step will be dedicated to local characterizations for the different configurations: micro-indentation and pull-out tests of particles will be investigated to provide information on the gradient of elastic modulus from the matrix, ITZ, to the aggregate, and behavior. As a result, it will be possible to assess material the level of compatibility of an aggregate from a batch with a given binder by comparison with the reference.

References

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Additional information

The thesis will be carried out mainly in the laboratory of Pascal Institute at the Clermont-Auvergne University, in close collaboration with the other teams involved in the project (Gustave Eiffel University, GEOMAS and MATEIS at INSA Lyon, Navier Laboratory and the cement manufacturer VICAT)

Applicant's profile

Holder of an engineering degree or an M2R, the candidate will have to show quickly autonomy in order to optimize his working time. A specialization and/or a first professional experience (end-of-studies project for example) in materials chemistry and/or agro-resource sciences will be appreciated.

In particular, knowledge of DIC technique and numerical modulization will be a plus.

In addition to these technical skills, the candidate will have to demonstrate autonomy, team spirit, and an ability to vulgarize and communicate his/her work. He/she should have a strong interest in experimental work. Finally, he/she should be fluent in English, both written and spoken.

Applications and contacts

Interested candidates should send their CV with a cover letter *specifying their interest in the PhD subject*, a transcript of their M1 and M2 grades and a letter of recommendation from their internship tutor and their training supervisor.

These documents, *gathered in a single pdf file*, will be sent to:

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